EXHIBIT 1

UNITED STATES DISTRICT COURT
SOUTHERN DISTRICT OF NEW YORK

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MDL No. 1358 (SAS)

In Re: Methyl Tertiary Butyl Ether ("MTBE") Products Liability Litigation

Master File
C.A. No. 1:00-1898 (SAS)

This document relates to:

City of New York v. Amerada Hess Corp., et al., Hess Corp., et al.

No: 04 CV 3417

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EXPERT REPORT OF I. H. SUFFET, Ph.D

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March 9, 2009
Date

INTRODUCTION

I have been engaged by the Defendants in the case of City of New York v. Amerada Hess to consider the issues raised therein relative to the potential effect of low levels of MTBE upon the taste and/or odor of drinking water. As part of this engagement, I have been asked to review and comment upon the opinions in the report issued by Plaintiff's expert, Harry T. Lawless, PhD. The papers, reports and evidence which I have relied upon are described in the body of this report. I am being paid for my work in this case at the rate of $250 per hour with a minimum of $2,000 for any day or partial day related to deposition or trial, plus expenses. I have not provided deposition or trial testimony as an expert witness in any litigation in the last four years.

My primary professional focus has been teaching water quality science and environmental chemistry. Secondarily, I have been a consultant to the water utility industry or to others interested in drinking water issues, with a particular emphasis upon water quality issues relative to taste and odor. I was one of the principal technical advisors to and authors of the study of MTBE odor in drinking water conducted in 1997 in California known as the Stocking Study, which Dr. Lawless has referred to and relied upon as being the single most valuable and reliable study on that topic to be found. My current curriculum vitae which includes a listing of my publications is attached as Appendix C.

At the trial of this case, I intend to express the opinion to a reasonable degree of scientific certainty that the New York state maximum contaminant level (MCL) for MTBE in water of 10 ppb (ug/1) provides adequate aesthetic protection to consumers. Put another way, my expert professional opinion is that it would be unreasonable and unnecessary for the City of New York to adopt a treatment goal for MTBE below the State-required MCL because it is extremely unlikely that consumers will detect and object to any odor or taste associated with MTBE in drinking water containing less than the Odor Threshold Concentration (OTC) of 15 ppb established in the Stocking Study.

My supplementary and supportive opinions, all based upon a reasonable degree of scientific certainty and explained in more detail below, are as follows:

1. The Odor Threshold Concentration of a given odorant chemical is the best guide for the water utility industry to use in order to set so-called secondary treatment standards to avoid delivering drinking water which their consumers will find aesthetically unacceptable.
2. There have been a number of valid studies performed to determine the OTC for MTBE in drinking water. The low end of the resultant range is best represented by the Stocking Study, which derived a value of 15 ppb and which Dr. Lawless agrees is "…the most trustworthy estimate of the detection threshold for MTBE…" (Lawless #13)
3. It is scientifically inappropriate to attempt to derive individual threshold values or values applicable to population percentiles by either parsing the results of the Stocking Study or manipulating the data by statistical analysis methods not intended or prescribed by the ASTM 679 method.
4. Even if the level at which the most sensitive consumer can "detect" MTBE were relevant to water treatment decisions, there is no credible scientific evidence that MTBE can be detected in drinking water by smell or taste at levels of 1-2 ppb.

5. The other contaminants found in drinking water produced by the wells at issue in this case, particularly iron and chlorine, serve to interfere with or mask any taste or odor which might be associated with low levels of MTBE.

6. Field evidence based on actual MTBE concentrations and assessments of consumer reactions from several states supports the use of the New York State's MCL of 10 ppb as protective of consumers from taste and odor concerns.

BASIS OF EXPERT AND SUPPORTIVE OPINIONS

1. The Odor Threshold Concentration of a given odorant chemical is the best guide for the water utility industry to use in order to set so-called secondary treatment standards to avoid delivering drinking water which their consumers will find aesthetically unacceptable.

As a general principle, the USEPA and water utilities do not set secondary standards or operational concentration levels of odorants at the concentration detectable by the most sensitive consumer or detection by the most sensitive panelist in a laboratory study as will be explained below. Moreover, as Dr. Lawless concedes the recognition threshold is above the detection threshold and the level at which consumers will find the taste or odor objectionable is above that concentration (consumer objectionable level).

The odor threshold concentration (OTC) is a statistically determined experimental geometric mean that represents the level detected by 50% of the test subjects. OTC is the best scientifically quantitative reproducible experimental method to determine the secondary treatment standards to avoid delivering drinking water which consumers will find aesthetically unacceptable. The use of the OTC includes the consideration of populations below the OTC as the OTC does not determine the level at which persons are likely to perceive a distinctive taste or odor (i.e., be recognized) or the level at which consumers would find the substance objectionable.

Reliance on the OTC gives consideration to the fact that the level at which people "detect" an off odor is significantly below levels at which the consumer could recognize or describe the odor and well below the level which would impart an odor which the consumer would find objectionable. This gradation between detection, recognition and objection is conceded by Dr. Lawless and universally recognized in the field of drinking water science.[1]

No secondary USEPA drinking water odor standard or any goal set for an odorous chemical by a water utility has been set in reliance on the odor detection threshold of a few panelists from an OTC experiment or a small number of consumer complaints. This also explains the complete absence in the relevant literature of studies designed to determine odor thresholds for individuals. Secondary taste and odor standards have traditionally been based upon the understanding of water utilities that an odor detection threshold pertaining to the most sensitive consumers does not determine the acceptable odor standard for water consumers.

It should be noted in this regard first that the USEPA's secondary drinking water standard (for applicability to any odorant chemical) is set at a threshold odor number (TON) of 3 that is 65% above the odor detection concentration at 60 ^{o}C. Secondly, the accepted practice of water utilities is to set the taste and odor treatment goals based upon either the consumer objection level or the public acceptance level.

In practical terms, the consumer objection level or the public acceptance level value turn out to be greater than or equal to the odor threshold concentration of the chemical, as determined by the geometric mean of an expert or consumer panel odor threshold evaluation.[2] This is proven by the manner in which various water utilities established treatment goals for two non-toxic, highly odorous compounds, geosmin and 2-methylisoborneol (MIB).

Threshold odor number

The secondary drinking water standard for odor was promulgated under the authority of the Safe Drinking Water Act[3] and is intended to "prevent a substantial number of persons…..to discontinue (public water system) use." That quote well describes the appropriate strategy for water utilities with respect to consumer acceptance regarding taste and odor. Although there is no definition of the term "substantial" in the regulations, the TON of 3 means that protection of the most "sensitive individual" is not the USEPA's goal and indicates that there is an acceptable odor for drinking water.[4]

The TON "...is the greatest dilution of a sample with odor-free water yielding a definitely perceptible odor."[5] TON = A + B/A; where A = mL sample and B = mL odor-free water. For a TON of 3, a sample of 70 mL would be diluted to 200 mL with odor-free water. This means that a 65 % sample dilution to be just detectable is acceptable by the general population of consumers for any odorant, including MTBE, and this is in a tap water background and not a laboratory odor-free water background.

Accepted practices of water purveyors to set the goal for their water utility at a taste and odor achievable treatment goals based upon consumer complaints

Water utilities have themselves been individually trying to define levels of chemical odors that are acceptable by the public.[6, 7] This is defined here as the "public acceptance level". The public acceptance level is above the consumer objectionable level and is the level at which consumer complaints are received.

Two chemicals that cause earthy/musty odors in drinking water supplies, geosmin and MIB, provide a good illustration. These two chemicals are the primary taste and odor problem for water utilities throughout the world. Two case studies presented in detail for Philadelphia[8, 9] and the Metropolitan Water District of Southern California (MWDSC)[10] set achievable treatment goals based upon consumer perception in their drinking waters for geosmin and MIB at 10 ng/L. The lowest values of OTCs reported in the literature by expert panels for geosmin and MIB are 4 and 9 ng/L, respecitively, at room temperature.[11] The OTC is the geometric mean of the panelists tested. Thus, the utilities have chosen to set an achievable treatment goal based upon consumer perception in their drinking water to be near the OTC of the chemical i.e., the geometric mean of an expert panel odor threshold evaluation. It should also be noted that chlorine or chloramine disinfectants in drinking water do not react with geosmin and MIB but can mask their perception in tap water to consumers as discussed in more detail later in this report as well as in the report by Mackey, Suffet and Booth (2009).[12]

As part of my publication record, three articles and an "in press" Water Research Foundation report discuss the general approaches to develop secondary standards for drinking water. These are : 1) AWWA (2002)[13], 2) Suffet, Schweitzer and Khiari (2004)[14], 3) Suffet, Burlingame and Mackey (2008)[15], and 4) Mackey, Suffet and Booth (2009)[16].

Paper 1 presents geosmin, MIB and MTBE as potential taste and odor problem chemicals in drinking water. The history of regulatory attempts to limit tastes and odors in drinking water was described. This includes the secondary standard of a TON of 3 at 60^{o}C.[17] The method first appeared in the 9th edition of *Standard Methods* which was published in 1946. A TON of 3

agreed with the proposed European Community Standards of 1975[18] and the US Food and Drug Administration value.[19] The USEPA stated in the Federal Register "The TON level of 3 was decided to be appropriate because most consumers find the water at this limit acceptable…." The chlorine concentrations in tap water are governed by the Surface Water Treatment Rule[20] and the Stage 1 Disinfectant/Disinfection Byproducts Rule[21], which require a minimum of 0.2 mg/L chlorine leaving the treatment plant and a maximum of 4 mg/L chlorine based on a running annual average in the distribution system. Free chlorine can be the cause of background odors due to its odor and flavor threshold that ranges from 0.24 to 0.36 mg/L, respectively based on the most credible study that is available.[22]

Papers 1 and 2 discuss a series of regulatory options for six approaches and notes the problems to use these options. The second paper adds two other options, individual utility-community based levels to eliminate variable sensory response by using the Stocking et al.[23] methodology of determining the odor and taste threshold by a forced-choice ascending concentration series methods of limits (ASTM E-679)[24], with the addition of including the drinking water background matrix. The "individual utility-community based standard" is based upon OTC for a chemical adjusted to percent of community acceptance as defined by ASTM, E-1432-04[25] i.e. the MTBE geometric mean. In practice, consumers would be exposed to MTBE in their drinking water matrix that may be synergistic or antagonistic to the odor of MTBE. For example in paper 1, a utility was described that did not identify up to100 ug/L of MTBE in the water with consumer complaints. This was apparently because of high hardness or salt. Paper 1 stated "Therefore, optimally, the OTC at a water utility should be determined in the water matrix for the utility."

Papers 2, 3 and 4 also suggest that a USA based standard to develop with communities based upon another approach to determine a utility-community based standard. The Flavor Profile Analysis (FPA) method[26] is also used in this discussion. FPA intensity values for earthy/musty is another method of evaluating odor perception to trigger treatment. An FPA intensity value of 3 for earthy/musty is discussed. Geosmin and MIB at an FPA level of intensity 3 is considered the point that water utilities have chosen to be the level of concern using a panel of trained assessors.[27]

The Flavor Profile Analysis is a technique first perfected in the food industry[28] and has been adopted in the water industry as Standard Method 2170B.[29] The FPA method is used to develop an understanding of the odor types present and each intensity of these types (e.g., Odor type – earthy, Intensity 4). The intensity is rated by a reference standard, such as sugar water samples, with a 1 for threshold, 2 (very weak), 4 (weak), 6, 8 (moderate), 10, 12 (strong). An FPA of very weak to weak at an intensity of 3 has been found by water utilities to be near 10 ng/L, for a utility-community public acceptance level standard for geosmin and MIB in drinking water.

Therefore, secondary standards and operational concentrations for water utilities should be set such that the OTC determined by a panel is used and NOT the most sensitive consumer in a distribution system nor the most sensitive panelist in a laboratory study.

2. There have been a number of valid studies performed to determine the OTC for MTBE in drinking water. The low end of the resultant range is best represented by the Stocking Study, which derived a value of 15 ppb and which Dr. Lawless agrees is "…the most trustworthy estimate of the detection threshold for MTBE…" (Lawless #13)

It is my opinion, based on a reasonable degree of scientific certainty, that the best and most conservative value for the odor threshold concentration for MTBE is that which was calculated in Stocking et al.[30] using the then current edition of ASTM method 679. The ASTM method 679 is a rigorous and reproducible technique to determine the OTC, designed specifically for the establishment for water treatment goals. The OTC for MTBE determined by Stocking et al. pursuant to ASTM 679 was 15 ppb.[31]

As Dr. Lawless admits, the Stocking study was "…the most trustworthy estimate of the detection threshold for MTBE…"[32] The Stocking Study used a large (57 persons), diverse consumer panel. The study scrupulously followed the then current ASTM 679 method, which was specifically designed for the purpose of establishing water treatment goals. It was implemented by the National Food Laboratory, an experienced and properly certified testing facility which applied rigorous laboratory techniques and quality control methodologies. The Stocking Study results were properly calculated using the prescribed geometric mean statistical method. It has been replicated by at least one other research organization (Campden 2003).[33]

In his report, Dr. Lawless stated:

> "In the report known as Campden (2003)[8], the procedure is purported to be a replication of that of Stocking et al. and found a threshold at 56.7 ppb. However, this study used a fully counterbalanced triangle procedure. On half the trials, two MTBE samples and one water blank were given ("six possible orders" implies all possible combinations). This is not what was done by The National Food Laboratory for the Stocking study (see appendices to Malcolm Pirnie report) which followed the ASTM protocol."[34]

Dr. Lawless is incorrect. He misinterpreted two sentences in the Campden (2003) report that stated: "Each triangle test paired a water sample with one of the test concentrations. The set of samples are presented equally often in each of the six possible orders; this experimental design minimises any possible order and carryover effects." The six possible orders refers to the "order of presentation" of one cup containing the odorant and two cups containing the background water. I was present at all of the testing done at Campden that reproduced the Stocking study. The six triangle test presentations were:

1*, 2, 3
1*, 3, 2
3, 1*, 2
2, 1*, 3
3, 2, 1*
2, 3, 1*
(Note: 1* is the cup with the odorant, cups 2 and 3 contained background water; all cups were randomly labeled)

I am certain that this was the procedure that was followed.

Stocking concluded that the OTC for MTBE is 15 ppb. This is properly interpreted as being the concentration value below which only an insignificant number of consumers can be expected to "detect" the presence of some odor in pure water. This value, given the results of the 29 other studies conducted to determine MTBE's OTC (Appendix A), is at the low end of the range of results which gives me a high degree of confidence that treatment to the New York State MCL of 10 ppb will completely protect the subject water consumers.

3. It is scientifically inappropriate to attempt to derive individual threshold values or values applicable to population percentiles by either parsing the results of the Stocking Study or manipulating the data by statistical analysis methods not intended or prescribed by the ASTM 679 method.

Dr Berk, the statistical consultant on the Stocking et al. study, had substantial difficulty applying logistic regression analysis to the Stocking study data because the forced choice triangle method invites/requires guessing by the panelists. The Stocking et al. data does not lend itself to the type of manipulation suggested by Dr. Lawless using the so-called Abbott's Formula and logistic regression analysis. The ASTM Method E-679 does not indicate that it can or may be used to determine individual odor thresholds or the threshold levels applicable to prescribed percentiles for the public. In fact, the ASTM method E-679 is described "as a group OTC method". Trying to apply Abbott's formula or logistic regression analysis requires an inappropriate modification of the data derived by the ASTM 679 method.

There is an ASTM standard practice designed to determine the individual thresholds of panelists. This is ASTM Method E-1432. This method requires six tests by each panelist on different days. The ASTM Method E-1432 has never used to determine the OTC of individual panelist for MTBE. In fact, it has not been used in the drinking water field for any chemical to the best of my knowledge. This serves to support my opinion that the detection levels for individuals or small percentages of the population is simply not relevant to the determination of water treatment goals. The ASTM committee E-18 apparently accepted the ASTM Method E-679 for what it is "a group threshold method" and determined the group OTC only. The graphical presentation (Figure 2) in the Stocking paper merely indicates the variance of panelist responses in the study. It is not intended (as Dr. Lawless apparently understands) to be used to predict detection thresholds applicable to percentiles of the water consuming population.

As noted on the table in Appendix A, the 15 ppb odor threshold determined by the Stocking et al. study is the lowest of the 29 scientifically credible odor and flavor thresholds with one exception (13.5 ppb odor threshold in two publications by Shen et al. 1997a[35] and 1997b[36]). I agree with Dr. Lawless that the Stocking et al. study is an excellent study, but it is only one valid study out of many. Unfortunately, Dr. Lawless then makes the error of parsing the results of the Stocking study to prove his point of view.

In his expert report,[37] Dr. Lawless stated:

> "This data set also indicates that 10% of the population will detect MTBE at concentration levels of 1 – 2 ppb and 25% of the population at about 3 ppb[6]. These interpolated values are slightly more conservative but otherwise agree with the data set. For example, the ASTM method's individual best estimates show 10/57 (17.5%) of the test group reached their individual threshold estimates at 1.4 ppb. The fact that over 17% reached their individual threshold estimates at the lowest level tested indicates that some significant proportion of individuals may have sensitivity below that lowest tested concentration of 2 ppb. Had Stocking et al. extended the concentration series further in the lower direction we would have had a better estimate of these more sensitive individuals. In other words, the data are subject to a "floor effect" which renders the derived estimates in a conservative direction."

It is not valid to pick and choose the data that fits a particular point of view *a posteriori* to an investigation using an ASTM consensus method. The panel of experts under the jurisdiction of ASTM Committee E-18 on Sensory Analysis of Materials and Products devised a method to determine a geometric mean of the results of individual panelists. Best estimate thresholds for individual panelists are determined by presenting three cups each of ascending concentrations of a substance (i.e. MTBE) in a medium (i.e. water) and panelists are asked to pick the cup containing the substance from the two other cups that do not contain the substance (forced-choice-triangle test or FCT).

In other words, the data collected under the ASTM method should be viewed as a whole and not manipulated or pulled apart to fit a pre-formed conclusion. One of the reasons for determining a group threshold concentration using a forced choice triangle method based on dozens of panelists is that individual panelists have one chance in three of *guessing* the cup that is different in the group of three when they cannot actually detect the presence of the odorant being tested such as MTBE. Thus, there is one chance in three that each of the 10 panelists cited by Dr. Lawless chose the cup with the lowest concentration (2 ppb) by guessing.

The range of concentrations investigated in the Stocking study was 2 to 100 ppb, which encompassed virtually all of threshold odor and flavor determinations that had been published in reports or the literature up to that time. With the exception of the flawed Campden 1993 study, few of the other MTBE threshold studies had extended the lower part of the range of concentrations that were tested below 2 ppb (See Appendix A).

The Campden 2003 study results showed excellent agreement with the broad range of MTBE odor and threshold concentrations listed in Appendix A (i.e., 13.5 to 180 ppb). While 53 ppb is 3.5 times higher than the Stocking odor threshold of 15 ppb, it is close enough to be another good estimate of the odor and flavor threshold concentrations for MTBE. It is rare to find a complete replication of a threshold odor determination by another research facility. When one factors in differences between the replicate studies (e.g. different laboratories, panelists sampled from a population in a different country), it is my opinion that the results of the Stocking study and the Campden 2003 study were consistent and compatible.

Therefore, extrapolations of the Stocking study to values of 1-2 ppb are not supported by good science. None of the threshold odor/flavor studies have determined levels of MTBE in water that are detectable by consumers at 1-2 ppb (Appendix A).

4. Even if the level at which the most sensitive consumer can "detect" MTBE were relevant to water treatment decisions, there is no credible scientific evidence that MTBE can be detected in drinking water by smell or taste at levels of 1-2 ppb.

In paragraph 5 of his expert report,[38] Dr. Lawless stated:

> "Based on the best study of odor detection of MTBE (methyl tertiary butyl ether), it is my opinion that MTBE can be detected by a significant proportion of the population by smell in drinking water at levels of 1-2 parts per billion (ppb). Based on the best study of odor detection of MTBE to date, this proportion is approximately 10%."

After his manipulation of the data in the Stocking study, Dr. Lawless claims that 10% of a population could be expected to detect MTBE at 1-2 ppb. No credible investigation published in the scientific literature has been designed to determine the level at which the most sensitive members of the population can "detect" an odor or taste in an MTBE-spiked sample. None of the OTC studies in the literature have demonstrated that MTBE can be detected by smell or taste in drinking water served to consumers at concentrations of 1-2 ppb. This is precisely why Dr. Lawless has had to extrapolate the data obtained by Stocking. If studies had been done on the subject of individual or most sensitive populations, Dr. Lawless could merely have reported their results.

One way to understand what concentration of MTBE can be detected by consumers is to look at the scientific information on MTBE odor and taste thresholds. Appendix A summarizes 31 odor and flavor (taste) characterizations for MTBE concentrations in water.[39] Out of 29 threshold studies (the two McGuire investigations were not threshold studies), the summary shows one study that found thresholds for MTBE less than 1 ppb—the report by the Campden dated 1993 (Campden 1993)[40]. In his report, Dr. Lawless admitted that the Campden 1993 study was obviously wrong and should not be relied on. Another study by Campden confirmed that the 1993 study was not replicable and therefore invalid.[41] The 2004 Campden study was referenced in a peer-reviewed paper published in 2007.[42]

None of the remaining 27 threshold investigations found odor or taste thresholds that were 1-2 ppb. For the 27 threshold investigations, the odor and flavor thresholds varied from 13.5 ppb to 180 ppb. Dr. Lawless incorrectly dismisses the validity of all of these threshold investigations except for the Stocking study. Prah et al. (1994)[43] determined an MTBE odor threshold of 180 ppb and was a peer-reviewed publication. Prah et al. used 38 untrained subjects and what appeared to be a method based on forced-choice triangle procedure of sample presentation of six binary dilutions of MTBE in distilled water.

Young et al. (1996)[44] was also a peer-reviewed study that determined one odor threshold and one taste threshold for MTBE in water. Young et al. published odor and flavor threshold concentrations for a total of 59 organic compounds in water. Young et al. used nine trained

female subjects and found an MTBE odor threshold of 34 ppb and a taste threshold of 48 ppb. Natural mineral water was spiked with six levels of MTBE and presented as paired comparisons to the panel members.

While Dr. Lawless is not happy with the Young et al. and Prah et al. studies, they are widely accepted and widely quoted in the taste and odor literature. Google Scholar cites 49 and 74 instances where Prah et al. and Young et al. have been referenced by other peer-reviewed articles, respectively.[45]

Three other studies, Shen et al. (1997a and 1997b)[46, 47] and Dale et al. (1997)[48], resulted in 18 odor and taste thresholds for MTBE and were conducted by water utility personnel using trained panel members from those utilities. The fact that the Orange County Water District (Shen) and the Metropolitan Water District of Southern California (Dale), two of the largest water utilities in the U.S., decided to conduct experiments to determine MTBE's OTC, absolutely proves my point that the OTC is the appropriate measure for water treatment goal setting. The method for training the panel of Dale et al. was the accepted method within the Food Industry as well as within the water industry.[49] Shen et al. used a trained panel of about 9 members and employed *Standard Methods* analytical method 2160B[50] as the method of presentation and the calculation method for thresholds. Shen et al. found odor thresholds for MTBE in a variety of different water qualities including chlorinated water that ranged from 13.5 to 43.5 ppb.

Dale et al. used a forced choice triangle presentation method and the Flavor Profile Analysis[51] method to determine odor and taste thresholds that ranged from 24 to 100 ppb. Four panelists were presented samples of water from the Colorado River and odor-free water spiked with varying concentrations of MTBE.

Even though it is not a peer-reviewed publication, Dale et al. has been cited in 17 references from a Google search. Also not a peer-reviewed publication, Shen et al. has been cited about a dozen times in Google references.

Based on my extensive experience in the taste and odor field associated with drinking water, it is clear that odor thresholds are good estimates of flavor thresholds. In his report, Dr. Lawless agreed. In my professional opinion, all of the publications cited above that have been discounted by Dr. Lawless are valid estimates of the odor and flavor (taste) thresholds for MTBE in water. Their validity serves to demonstrate that the New York State MCL for MTBE is more than sufficient to protect NYC water consumers.

5. The other contaminants found in drinking water produced by the wells at issue in this case, particularly iron and chlorine, serve to interfere with or mask any taste or odor which might be associated with low levels of MTBE.

It is my opinion, based on a reasonable degree of scientific certainty, that the odors and tastes emanating from the iron and chlorine found in the drinking water served from the groundwater in the Jamaica-Queens area would mask any low levels of MTBE present making impossible the detection at levels below 10 ppb of MTBE.

In paragraph 33 of his expert report, Dr. Lawless acknowledged the effect of other substances in water that can interfere with detection of odors:

> "Other factors in real life could mitigate against the detection of MTBE in some circumstances. For example, the presence of background odors in any environment would tend to mask or cover up an odor present in a water sample."

However, Dr. Lawless does not acknowledge that there are substances in the NYC groundwater that would definitely affect the ability of consumers to detect low levels of MTBE in their water.

It is well known in taste and odor testing of drinking water that the presence of chemicals that affect the taste and odor characteristics of tap water can mask or obscure the presence of other chemicals at or near their threshold odor concentrations. Doty (2003) stated, "Usually when two single compound odorants are mixed together, the perceived intensity of one or both is altered substantially, the net result being a lowering of the intensity of the components."[52]

Chlorine Interference with Odor and Flavor Detection

Studies have documented an antagonistic effect of free chlorine on the intensity of earthy/musty odorants found in drinking water, geosmin and MIB.[53] The higher the chlorine concentration, the lower the intensity of the earthy/musty odorants. This was recently confirmed for geosmin at low ng/L levels and chlorine at mg/L, drinking water concentrations.[54]

Krasner, McGuire and Ferguson (1985) described a real-world chlorine masking case history.[55] In 1979, the Metropolitan Water District of Southern California experienced its worst taste and odor incident in over 35 years. Because the FPA method had not been adapted to drinking water at that time, water samples from the water treatment plant effluents were tested by the Threshold Odor Number. No musty odor problem could be detected at the water treatment plant effluents. However, samples brought in from the far reaches of the distribution system had the offensive musty flavor causing the complaints. Later investigations established that the problem was caused by the blue-green algae metabolite, MIB.

Concentrations in the source water reservoir (Lake Mathews) of approximately 10 to 20 ng/L were later discovered to pass through the water treatment plants to the ends of the distribution system without significant changes in concentration. The musty flavor problem was not detected in plant effluent samples primarily due to free chlorine that was present in the water at that location, which masked the musty flavor problem. When the plant effluent samples were taken into the mouth, chlorine could easily be detected. As the water traveled through the distribution system, the chlorine residual degraded and as the chlorine concentration decreased, the offensive musty flavor was unmasked, resulting in musty consumer complaints.

Shen et al. (1997a and 1997b)[56] investigated the effect of chlorine and chloramine concentrations on the threshold odor of MTBE. Shen et al. found that in the presence of a low level of free residual chlorine, about 0.2 mg/L, the threshold odor level of MTBE increased.

Table 1 lists the minimum, maximum and average free chlorine concentrations in the Jamaica-Queens area served by groundwater from 1998 to 2007. The chlorine residual data was obtained from Consumer Confidence Reports prepared by NYCDEP.

The threshold odor and flavor concentrations for free chlorine have been estimated at various levels but the most credible study found that free chlorine odor and flavor thresholds ranged from 0.24 to 0.36 mg/L, respectively.[57] It is my opinion, to a reasonable degree of scientific certainty, that the ability of a consumer to detect MTBE in tap water in the Jamaica-Queens area would be significantly affected by the presence of free chlorine at the concentrations shown on Table 1. Therefore, detections by consumers in their homes associate with the presence of MTBE at the New York State MCL concentration (10 ppb) would be virtually non-existent.

Table 1. Free Chlorine Residuals in Groundwater Service Area of Jamaica Queens, mg/L

Year	Number of Samples	Minimum	Maximum	Average
1998	1477	0.02	1.65	0.73
1999	1229	0.02	1.16	0.69
2000	1124	0.0	1.5	0.6
2001	648	ND	1.4	0.6
2002	624	0.04	1.9	0.9
2003	401	0.08	1.7	0.8
2004	358	0.00	1.42	0.58
2005	112	0.04	1.14	0.59
2006	128	0.02	1.30	0.66
2007	18	0.29	1.23	0.73

Iron Interference with Odor and Flavor Detection

In addition to free chlorine, significant concentrations of iron are present in water distributed to NYCDEP customers in the Jamaica-Queens area. Figure 1 shows box and whisker plots of iron concentrations from the area served by groundwater in Jamaica-Queens. Data are plotted for iron concentrations from samples collected and analyzed by NYCDEP in the distribution system associated with compliance sampling and complaint sampling. Well data and other complaint sampling results are also presented.

The 95 percent confidence interval of "taste" thresholds for iron has been estimated to be 0.040 to 256 ppm.[58] The iron concentrations shown on Figure 1 fall within this range, which means that iron should be discernable to consumers who are experiencing iron in their tap water.

It has been suspected for some time, that the metallic flavor of ferrous iron was not strictly due to taste but also had an odor component.[59] Recent research has shown that the typical metallic odor of iron metal touching skin is caused by volatile carbonyl compounds (e.g., aldehydes, ketones) produced through the reaction of skin peroxides with ferrous ions (Fe^{2+}) that are formed in the sweat-mediated corrosion of iron.[60]

Recent research has focused on iron-skin reactions, but the characteristic "iron odor" detected by retronasal stimulation from drinking water containing iron is similar to the odor developed when iron is in contact with skin. Dr. Lawless has published a paper on the "smell of iron."[61]

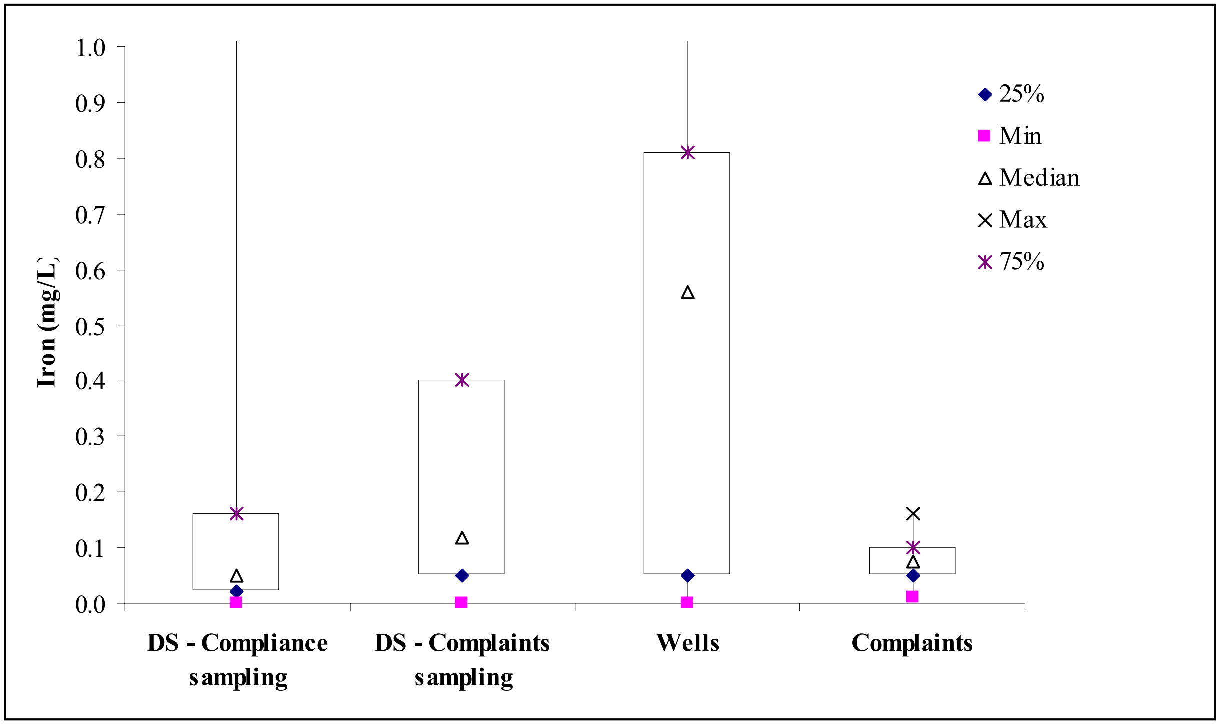

Figure 1. Box and whisker plot summarizing all iron data from distribution system, wells, and complaints. Note that maximum iron values for distribution system/compliance (3.62 mg/L) and complaints (63.18 mg/L), and wells (4.89 mg/L) are out of range in the y-axis. All values of iron recorded as below detection limits were set to zero.

In summary, the significant concentrations of chlorine and iron in the water served to NYCDEP consumers in the Jamaica-Queens area would mask the presence of other odorants. Thus, consumers would not detect MTBE in tap water in this area unless the MTBE concentrations were much higher than the Stocking study odor threshold of 15 ppb which is, of course, 50% higher than the New York State MCL.

6. Field evidence based on actual MTBE concentrations and assessments of consumer reactions from several states supports the use of the New York State's MCL of 10 ppb as protective of consumers from taste and odor concerns.

Several investigations have demonstrated that consumers do not perceive low concentrations of MTBE in water served to them: Maine Investigation, Experiences in New Hampshire, Suffolk County Complaint Analysis and Assessment of Complaints from Jamaica Queens.

State of Maine MTBE Data
A government department in the State of Maine published a preliminary report on the impact of MTBE in drinking water.[62] The investigators did a statistical study of interview responses of study participants who were on private water supplies where MTBE had been detected in their tap water (150 households).

The findings can be summarized in one statement: "No significant difference was found in frequencies of MTBE detection among individuals answering yes versus no regarding presence of a water odor or taste ($p < 0.1$)." There was no concentration dependence (0.1 to 35 ppb or greater concentrations) on the perceived abilities of residents to detect MTBE in their household supply. This finding demonstrates that the ability of residents to actually detect MTBE in their tap water was inconsistent and they had a lot of trouble discerning the presence of MTBE even at levels as high as 35 ppb. Based on this result of real people in real tap water consumption situations, the 10 ppb New York State MCL is protective of consumers.

New Hampshire MTBE Detection Information
The State of New Hampshire is engaged in a lawsuit against several oil companies and has over the last few years been collecting information on MTBE in wells. Fred McGarry is the Assistant Director of the New Hampshire Department of Environmental Services, Waste Management Division. In an email from Fred McGarry to Ken Colburn[63], a former New Hampshire environmental official, Mr. McGarry reviewed several case histories of high levels of MTBE in New Hampshire private wells and the inability of people drinking the water to notice any taste and odor problems. Levels of MTBE in the private wells ranged up to 50 ppb and far above 100 ppb in some samples. In the email, Mr. McGarry stated:

> "As you can see, although taste and odor tests under controlled laboratory conditions show individuals able to detect MtBE at levels in the range of 5-20 ppb, the general public may not complain about the presence of the compound until the concentration is above 100 ppb."

Suffolk County MTBE Data
In 2007, McGuire presented an analysis of 47,745 complaints that were made by customers of the Suffolk County Water Authority (SCWA) over the period 1999 to 2005.[64] SCWA serves groundwater to 1.1 million customers. Also presented by McGuire in the same report were the MTBE concentrations in 19 focus wells in the SCWA system. These well data showed that for years at a time, MTBE concentrations of about 3 ppb or higher were being served to consumers. During this period, consumers filed over 13,000 complaints associated with rusty water and

chlorinous tastes and odors. However, there was no evidence that the MTBE in distribution system samples was generating any of the consumer complaints. On page 118, McGuire stated:

> "It is my opinion, based upon a reasonable degree of scientific certainty, that SCWA had a very high incidence of complaints for a variety of water quality problems. However, there has been no link, based on actual data, between the occurrence of MTBE in the SCWA distribution system and any taste and odor complaints."

The SCWA MTBE concentration and complaint datasets described the largest example of low level exposure of MTBE to consumers over many years that I am aware of. For SCWA, no link between the low levels of MTBE and complaints has ever been made. These data show that a 10 ppb MCL for MTBE in New York State for drinking water would be protective and that MTBE concentrations in the range of 1-2 ppb would not elicit any consumer complaints.

Jamaica Queens MTBE Data and Complaints

As stated on the NYCDEP website,[65] the Jamaica Queens area served by groundwater in 2007 encompassed a small part of the NYC water supply:

> "Located in southeastern Queens, the Groundwater System covers an area of approximately 5.5 square miles. The neighborhoods connected to the Groundwater System include: Cambria Heights, Hollis, Holliswood, Jamaica, Kew Gardens, Queens Village, Richmond Hill, St. Albans, South Jamaica, and South Ozone Park."

About 100,000 people are currently supplied by the groundwater system. In years past, up to 350,000 people could be served by the groundwater system. Most of the Jamaica-Queens service area operated by NYCDEP has been served in recent years by the Catskill Delaware surface water supply. Currently, groundwater provides a small part of the water served to customers in this area with only one well operating for limited time periods in 2006 and 2007. Figure 2 shows the pumping rates by well for the groundwater system from 2004 to 2007.

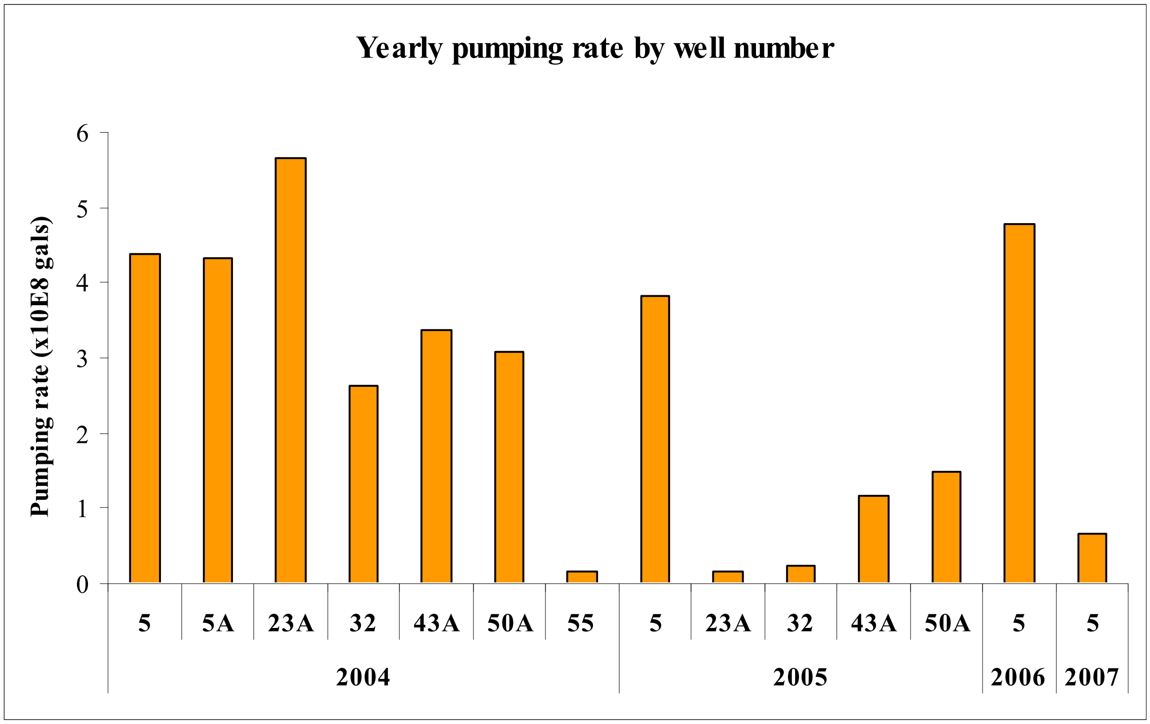

Figure 2. Yearly Pumping Rate for NYC Groundwater Wells, 2004-2007 by well number

In prior years stretching back to the acquisition of the Jamaica Water Supply Company in 1996, more wells were pumped to serve this area than are currently being used. Figure 3 for 2004 shows the complicated distribution of surface and groundwater for only one year.[66] No records have been provided by plaintiffs which identified the areas of Jamaica-Queens that were served by specific wells during clearly defined time intervals. It is not possible for defendants to recreate records of this important confluence of data when NYCDEP apparently does not have this information.

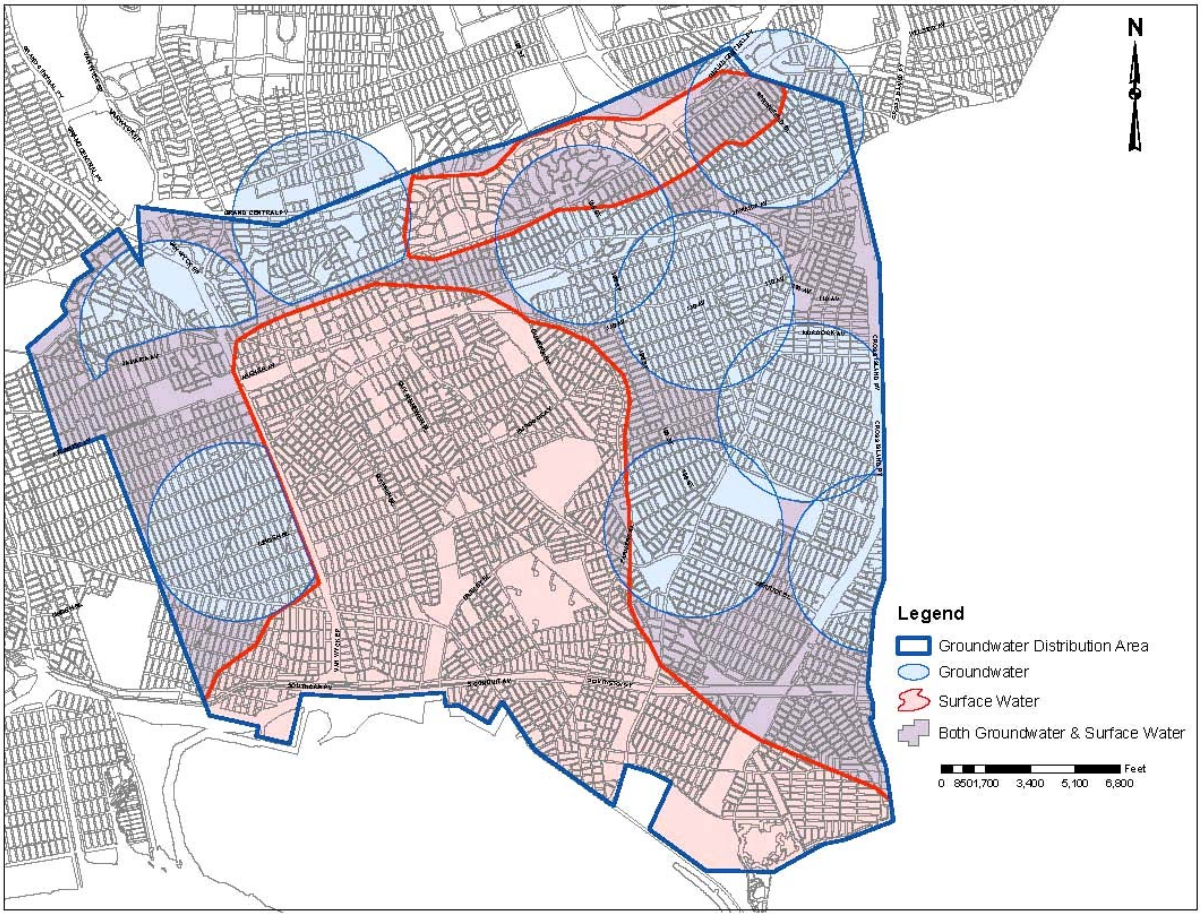

Figure 3. 2004 Jamaica Queens Distribution Areas for Groundwater and Surface Water Supplies (http://www.nyc.gov/html/dep/html/drinking_water/groundwater04.shtml)

Therefore, my report will use existing data to try and relate customer complaints from the Jamaica-Queens area to MTBE data provided by plaintiffs in space and in time. Plaintiffs provided several files of customer complaints from the Jamaica-Queens area made during the period 1994 to 2008. One of those files is claimed by plaintiffs to represent 356 taste and odor complaints due to MTBE. No evidence is provided that substantiates that claim. Figure 4 shows a pie chart of the descriptor categories used by the customers making the 356 so-called MTBE complaints.[67] A little over half of the descriptors listed on the spreadsheet were related to chemical odor or taste or contained the complaint code QA2. Based on my experiences with customer perceptions, chlorine odor is very often described as "chemical" or "medicinal" by untrained members of the public. A total of 41 percent of the complaints are categorized with general terms such as "bad" or "odor" or "taste." None of the notes in the complaint spreadsheet properly identify the "sweet solvent" characteristic of MTBE which is the characteristic odor of the compound above the odor or taste recognition threshold. Therefore, there is no evidence that any of the 356 complaints have anything to do with the presence of MTBE in distributed water.

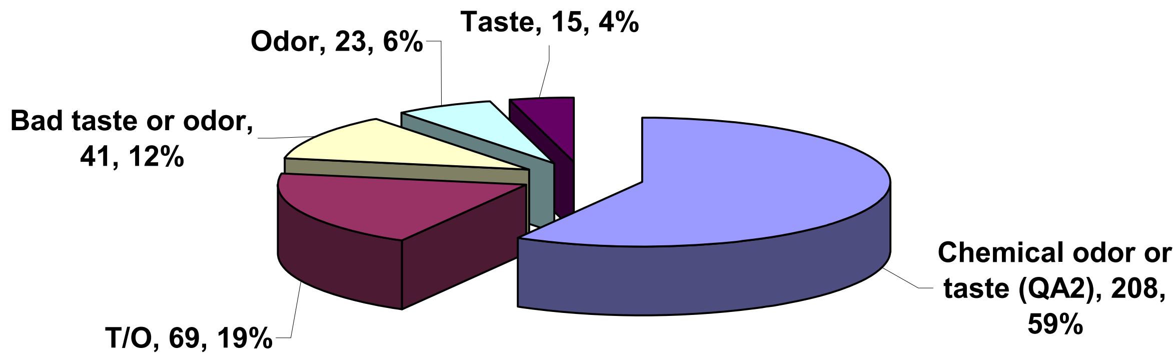

Figure 4. Descriptors from 356 Taste and Odor Complaints

In addition to the 356 alleged MTBE taste and odor complaints, plaintiffs provided defendants an Excel spreadsheet containing 1476 taste and odor complaints from the Jamaica Queens service area. Figure 5 is a pie chart of the complaint descriptors for the 1476 taste and odor complaints that had the 356 alleged MTBE complaints removed from the file for a total of 1120 complaints. Figure 5 shows that not one of the "Chemical (QA2)" complaint codes was left after the 356 so-called MTBE complaints were extracted. Obviously, plaintiffs assumed (incorrectly) that all chemical taste and odor complaints were due to MTBE. There are no data or scientific literature to support such an assumption. As stated previously, there is substantial experience from water utilities that consumers often describe a chlorine odor as "chemical." There are hundreds of chlorine, metallic (no doubt due to elevated iron levels), sewer and musty/stale complaints in the 1120 complaint file.

The 356 complaint descriptors of the so-called MTBE complaints are likely describing taste and odor problems that have nothing to do with MTBE.

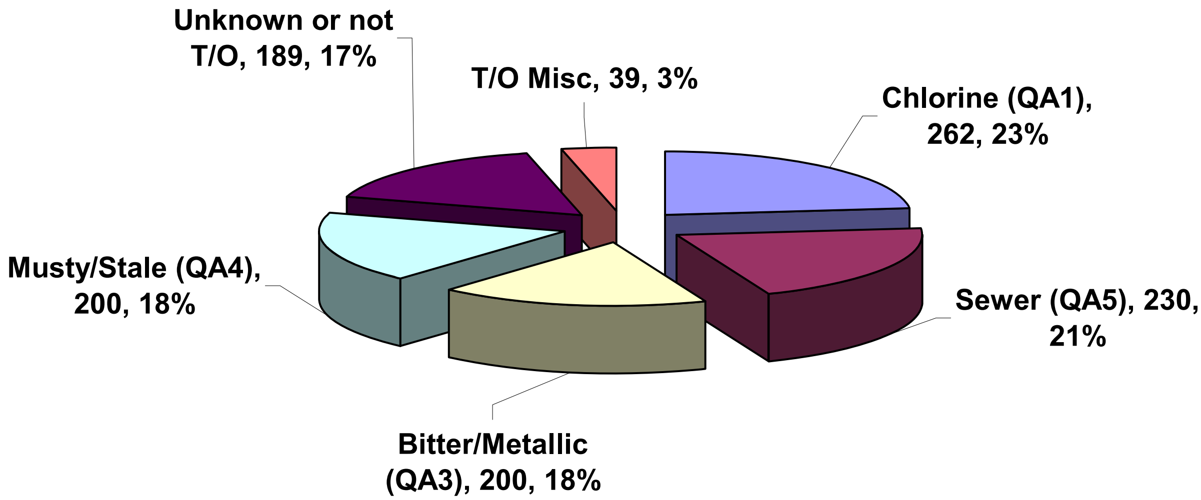

Figure 5. Descriptors from 1120 Other Taste and Odor Complaints

Figures 6 to 9 are GIS-created maps for the years 2004 to 2007 with the so-called 356 MTBE complaints for those years plotted on them. All maps in this report were developed using ArcGIS Version 9.2. Geocoding of complaint addresses was undertaken using TeleAtlas Streetmap Premium Version 10.1. Also identified on the maps are the areas identified by NYCDEP on their website that received groundwater or were supplied surface water from the Catskill Delaware surface water supply.

Table 2 summarizes by year the number of alleged MTBE complaints that were located in the groundwater served areas versus the alleged MTBE complaints that were actually located in the surface water-supplied area. The vast majority of complaints for these years were not even made by people living in the areas served by groundwater. Figure 10 summarizes the totals for Table 2 showing that only 9% of the alleged MTBE complaints for these four years were from households on groundwater. There is no reason to believe that the same situation did not exist in previous years stretching back to 1996 when NYCDEP acquired the Jamaica Water Supply Company.

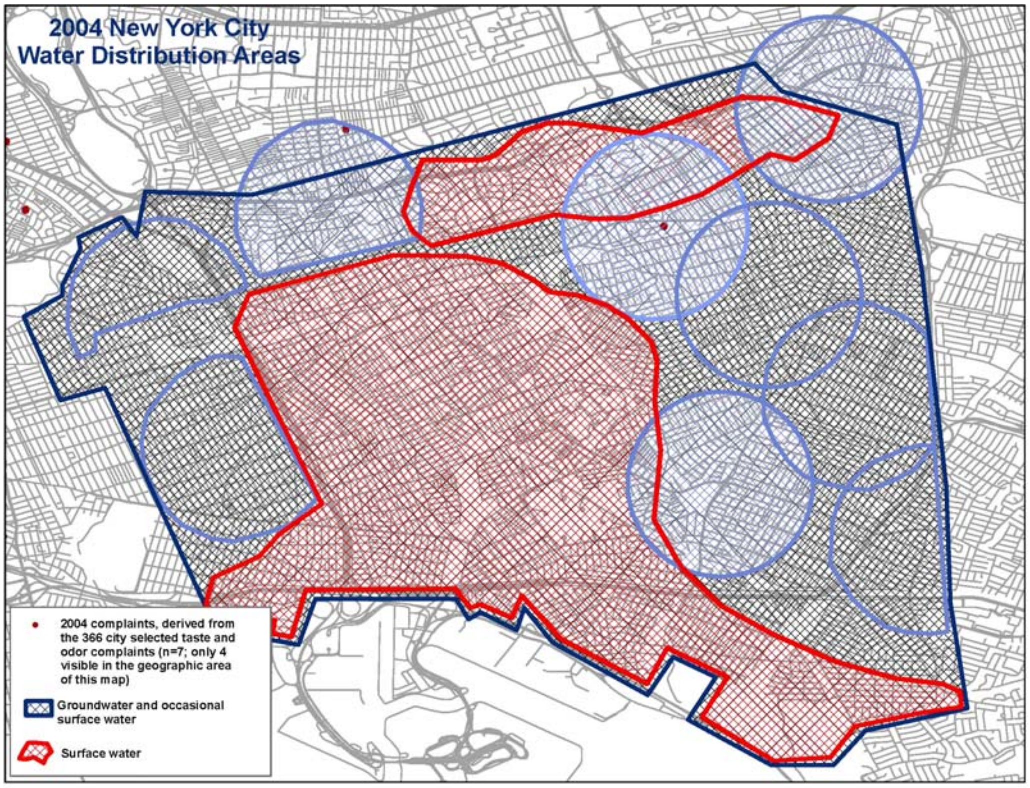

Figure 6. 2004 Alleged MTBE Complaints and Groundwater Distribution Areas

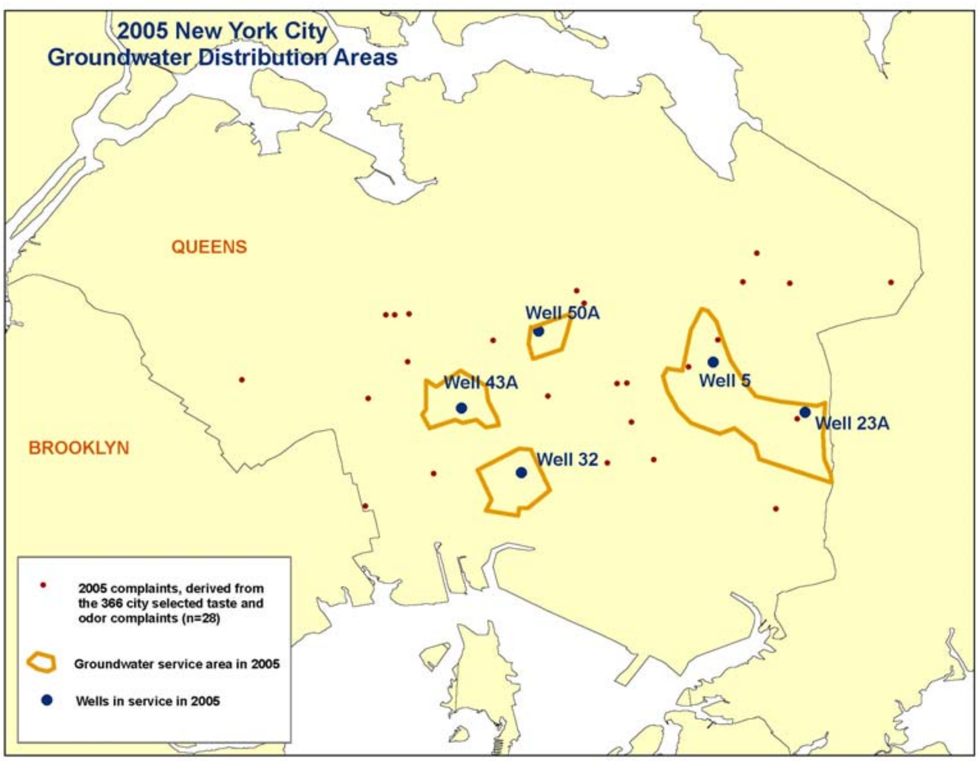

Figure 7. 2005 Alleged MTBE Complaints and Groundwater Distribution Areas

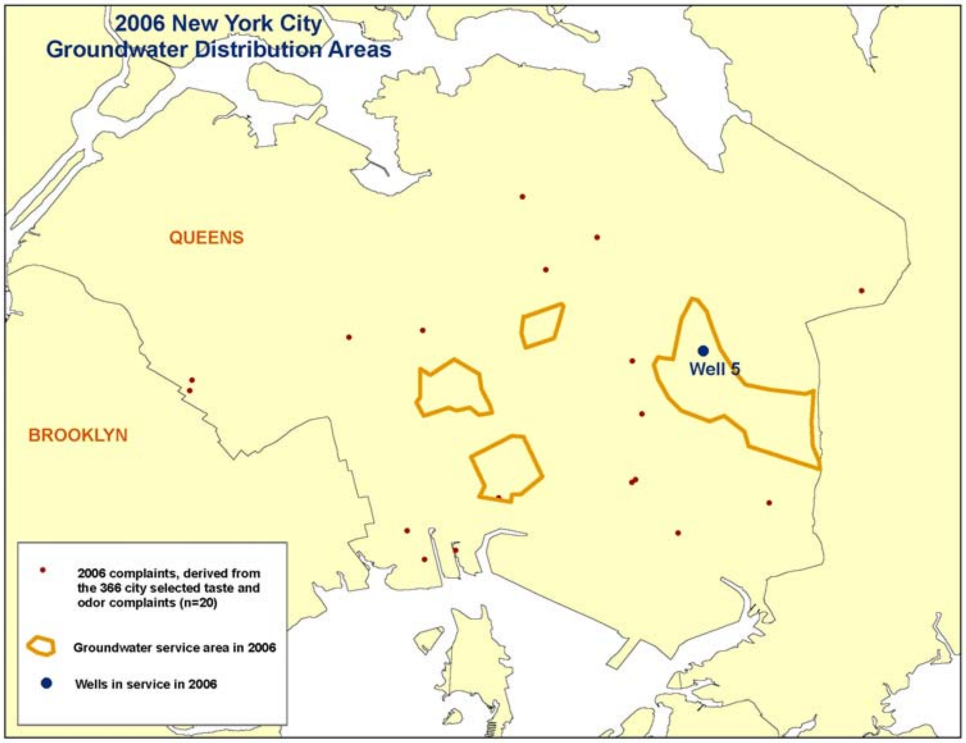

Figure 8. 2006 Alleged MTBE Complaints and Groundwater Distribution Areas

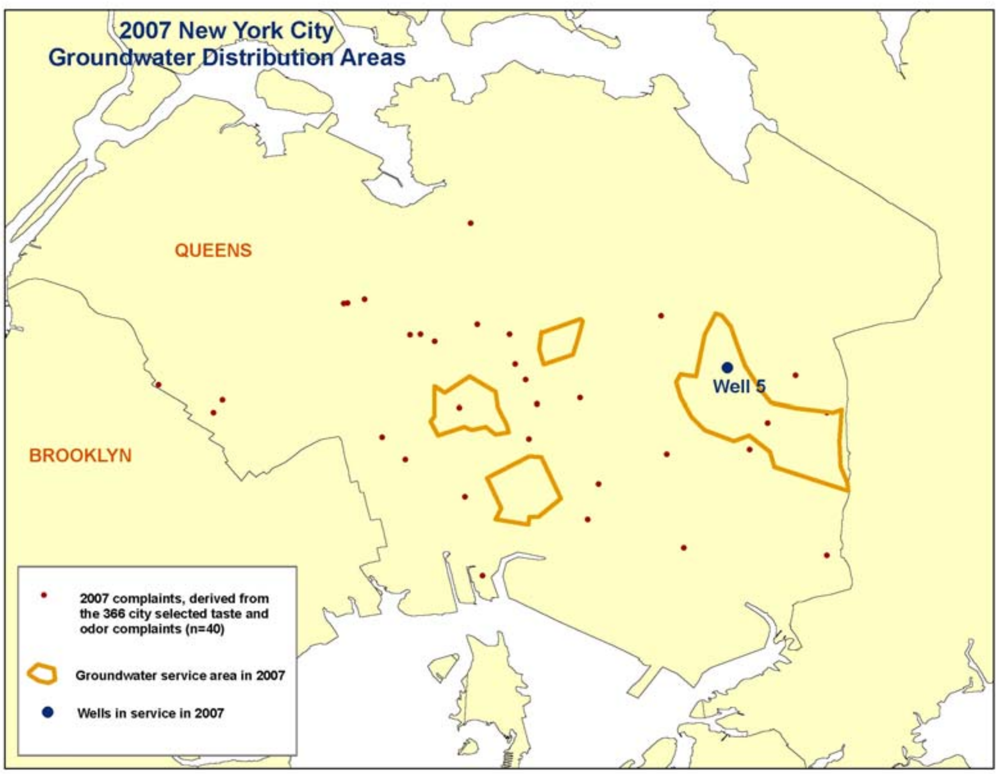

Figure 9. 2007 Alleged MTBE Complaints and Groundwater Distribution Areas

Table 2. Summary of Complaint Locations, 2004-2007

Year	Number Complaints in Groundwater Service Area	Number Complaints in Surface Water Service Area	Total
2004	2	5	7
2005	3	25	28
2006	1	19	20
2007	3	37	40
Totals	9	86	95

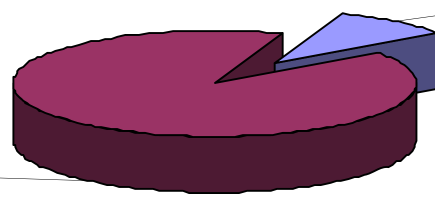

Figure 10. Complaint Location Summary, 2004-2007

Appendix B contains overview maps of all compliance sample sites for which MTBE was detected, and for which there are taste and odor complaints located within a radius of 1 mile of the sample site, and dated within +/- 1 week of the sample date. The one mile radius boundary is a generous geographical depiction of the area that might be represented by MTBE data from a sample site in the area that is serving the identified complaint location. Similarly, the +/- 1 week time frame is a generous time period that might relate the MTBE data from the compliance sampling site and the recorded complaints. Similar to the maps shown in Figures 6 to 9 the maps in Appendix B were developed using ArcGIS Version 9.2. Geocoding of complaint addresses was undertaken using TeleAtlas Streetmap Premium Version 10.1.[68]

In Appendix B, Figure B-1 is a map showing NYCDEP compliance sampling sites with MTBE data (MTBE measurements from file: Excel1/VOC) and the locations of 10 taste and odor complaints that Plaintiffs alleged are related to MTBE. None of the remaining 346 complaints were in any way related to measured values of MTBE. Also, 182 MTBE concentrations above the detection level of 0.5 ppb were unrelated to any complaints in space and time. Appendix B maps provide an illustration of the proximity of sampled sites to one another and to taste and odor complaints. The alleged MTBE complaints occurred from January 1994 to January 2008. Figures B-2 to B-11 show that ***only ten*** of the 356 so-called MTBE complaints were anywhere near in space and time water samples with measured levels of MTBE. It is likely that these 10 complaints were coincidentally associated with the MTBE data due to chance.

From 1994 to 2008, groundwater was served to 100,000 to 350,000 customers in the Jamaica Queens area of NYCDEP. If MTBE were really causing customers to complain about taste and odors in drinking water, I would expect that hundreds to thousands of complaints would be associated with the hundreds of measured levels of MTBE in the distribution system at compliance points. Obviously, 10 complaints associated by chance are no where near hundreds to thousands of expected complaints.

In summary, there is no reason to believe that the 356 alleged MTBE taste and odor complaints had anything to do with MTBE in water served to the complaining homes, because:

1. Plaintiffs have neither described how the 356 complaints were chosen nor how they relate to MTBE levels in tap water.
2. None of the 356 complaint descriptors are related to the odor characteristic of MTBE in water which is described as "sweet solvent." The "chemical" taste and odor complaints were likely due to chlorine concentrations in the water that were above the odor/flavor thresholds for chlorine.
3. Maps on the NYCDEP website when overlaid with the geocoded complaints showed that the vast majority of complaints for 2004 to 2007 were in areas that were NOT served by groundwater.
4. An analysis of MTBE data in compliance samples and alleged MTBE complaints showed that only 10 of the 356 complaints were even loosely associated in space and time with MTBE data. Even these 10 complaints have not been proven by plaintiffs to be caused by MTBE because no samples were collected from the complaining homes and analyzed for MTBE. The 10 complaints mapped in Appendix B could obviously be due to coincidence.

Health Canada
Health Canada, Water Quality and Health Bureau, agreed that the threshold determined by the Stocking study should be viewed in its entirety when it recently established an Aesthetic Objective of 15 ppb for MTBE based on the Stocking study threshold of 15 ppb.[69]

In the Health Canada Guideline Technical Document setting the Aesthetic Objective for MTBE, that agency agreed that an odor threshold is appropriate for describing threshold responses:

> "The most suitable and sensitive parameter on which to base a drinking water guideline for MTBE is odour. A study of human volunteers found that most would consider the water acceptable for consumption at a level of 15 μg/L for MTBE based on its odour threshold."

Summary Of Threshold And Consumer Exposure Studies
Dr. Lawless is not justified in opining that MTBE can be detected by a significant number of people in drinking water at concentrations of 1-2 ppb. No threshold odor/flavor study has found levels anywhere near 1-2 ppb. The complete absence of consumer reactions in distribution systems with measured concentrations of MTBE far above 1-2 ppb have supported the contention that the level of MTBE that is perceptible or objectionable to consumers is well in excess of the New York State MCL of 10 ppb.

REFERENCES

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[1] Mackey, E.D., Suffet, I.H. (Mel), and Booth, S.D.J., *A Decision Tool for Earth/Musty Taste and Odor Control*, Water Research Foundation (formerly AWWA Research Foundation), Report 3032, Denver, Colorado, In Press 2009.

[2] Suffet, I. H. (Mel), Schweitzer, L., and Khiari, D., "Olfactory and Chemical Analysis of Taste and Odor Episodes in Drinking Water Supplies", *Re/Views in Environmental Science and Bio/Technology*, 3(1), 3–13. 2004.

[3] USEPA, National Secondary Drinking Water Regulations. Final Rule. *Fed. Reg.*, 56:20:3526, 1991.

[4] USEPA, National Secondary Drinking Water Regulations. Final Rule. Fed. Reg., 44:140:42195, 1979.

[5] APHA, *Standard Methods for the Examination of Water and Wastewater* (20th edition), 1999.

[6] Suffet, I. H. (Mel), Burlingame, G., and Mackey, E.D., "Controlling Taste and Odor Events for the City of Philadelphia USA: A Case Study", *Water Science and Technology: Water Supply,* 8(2), 135-141, 2008.

[7] Mackey, Suffet and Booth 2009

[8] Mackey, Suffet and Booth 2009

[9] Suffet, Burlingame and Mackey 2008

[10] Mackey, Suffet and Booth 2009

[11] Suffet, I. H., Mallevialle, J, and Kawczynski, E., *Advances in Taste-and-Odor Treatment and Control*, American Water Works Research Foundation, American Water Works Association, Denver, Colorado, 1995.

[12] Mackey, Suffet and Booth 2009

[13] AWWA, Water Quality Division Taste and Odor Committee, Committee Report "Options for a Taste and Odor Standard," *Jour. AWWA,* 94:6, 80-87, 2002.

[14] Suffet, Schweitzer and Khiari 2004

[15] Suffet, Burlingame and Mackey 2008

[16] Mackey, Suffet and Booth 2009

[17] USEPA 1979

[18] *EC—Official Journal of the European Communities*, 18:6 (September 18) 1975.

[19] USFDA (US Food and Drug Administration) Quality Standards for Foods with No Identity Standards—Bottled Water, 12 CFR Part 103, 4-45, 12172, 1979.

[20] USEPA, National Primary Drinking Water Regulations: Filtration and Disinfection; Turbidity, *Giardia lamblia*, Viruses, Legionella, and Heterotrophic Bacteria. Final Rule. Fed Reg., 54:124:27544, 1989.

[21] USEPA, National Primary Drinking Water Regulations: Disinfectants and Disinfection Byproducts [Stage 1 Disinfection Byproducts Rule], *Federal Register*, 63(241), pp. 69389-69476, December 16, 1998.

[22] Krasner S.W., and Barrett S.E., Aroma and Flavor Characteristics of Free Chlorine and Chloramines. *Proceedings of the AWWA Water Quality Technology Conference,* Denver, CO, December 2-5, 1984.

[23] Stocking, A.J., Suffet, I.H., McGuire, M.J., and Kavanaugh, M.C., "Implications of an MTBE Odor Study for Setting Drinking Water Standards," *Jour. AWWA*, 93(3):95-105, 2001.

[24] ASTM (American Society for Testing and Materials), "Standard Practice for Determination of Odor and Taste Thresholds by a Forced-Choice Ascending Concentration Series Method of Limits," designation E679, West Conshohocken, Pennsylvania, 1979, 1997 and 2004.

[25] ASTM (American Society for Testing and Materials), "Standard Practice for Defining and Calculating Individual and Group Sensory Thresholds from Forced-Choice Data Sets of Intermediate Size," designation E1432, West Conshohocken, Pennsylvania, 2004.

[26] APHA 1999

[27] American Water Works Association, Flavor Profile Analysis: Screening and Training of Panelists, AWWA, Denver, Colorado, 1993.

[28] Caul, J.F., "The Profile Method of Flavour Analysis," in *Advances in Food Research*, (E.M. Mrak and G.F. Stewart, eds.) 7:1-40, Academic Press, New York, 1957.

[29] APHA 1999

[30] Stocking et al. 2001

[31] Stocking et al. 2001

[32] Lawless, H.T., "Expert Report of Harry T. Lawless, Ph.D.," prepared for City of New York v. Amerada Hess Corp., et al., 04 Civ.3417, United States District Court, Southern District of New York, February 5, 2009.

[33] Campden and Chorleywood Food Research Association Group, "Consumer Odour Threshold of Methyl Tertiary Butyl Ether (MTBE) in Water," Report No. S/REP/74638/2, November 12, 2003.

[34] Campden 2003

[35] Shen, Y.F., Yoo, L.J., Fitzsimmons, S.R., and Yamamoto, M.K., "Threshold Odor Concentrations of MTBE and Other Fuel Oxygenates," Division of Environmental Chemistry Preprints of Extended Abstracts, American Chemical Society, Vol. 37, No.1, April 1997a.

[36] Shen, Y., Bergen, M., Yoo, L., and Fitzsimmons, S.R., "Effect of Residual Chlorine on the Threshold Odor Concentrations of MTBE in Drinking Water," Proceedings of the AWWA Water Quality Technology Conference, Denver, Colorado, 9 pages, November 9-12, 1997b.

[37] Lawless 2008

[38] Lawless 2008

[39] McGuire, M.J., "Expert Report of Michael J. McGuire, PhD, PE, BCEE," Prepared for United Water New York, Inc. v. Amerada Hess Corp. et al., 04 Civ. 2389, and County of Suffolk and Suffolk County Water Authority v. Amerada Hess Corp. et al., 04 Civ. 5424, United States District Court, Southern District of New York, March 1, 2007a.

[40] Campden Food and Drink Research Association, "Flavour and Odour Thresholds of Methyl Tertiary Butyl Ether (MTBE) in Water," work commissioned by Malcolm Dawson, ARCO Chemicals, report authorized by Nerys Griffiths, March 8, 1993.

[41] Campden and Chorleywood Food Research Association Group, "Flavour and Odour Thresholds of Methyl Tertiary Butyl Ether (MTBE) in Water," Report No. S/REP/74638, January 5, 2004.

[42] Suffet, I.H. (2007). A Re-Evaluation of the Taste and Odour of Methyl Tertiary Butyl Ether (MTBE) in Drinking Water. *Wat. Sci. Technol.*, 55(5):265-273.

[43] Prah, J.D., Goldstein, G.M., Devlin, R., Otto, D., Ashley, D., House, D., Cohen, K.L., and Gerrity, T., "Sensory, Symptomatic, Inflammatory, and Ocular Responses to and the Metabolism of Methyl Tertiary Butyl Ether in a Controlled Human Exposure Experiment," *Inhalation Toxicology*, Vol. 6, No. 6, pp. 521-538, 1994.

[44] Young, W.F., Horth, H., Crane, R., Ogden, T., and Arnott, M., "Taste and Odour Threshold Concentrations of Potential Potable Water Contaminants," *Wat. Res.*, Vol. 30, No. 2, pp. 331-340, 1996.

[45] http://scholar.google.com searched February 19, 2009.

[46] Shen et al. 1997a

[47] Shen et al. 1997b

[48] Dale, M.S., Moylan, M.S., Koch, B., and Davis, M.K., "MTBE: Taste-and-Odor Threshold Determinations Using the Flavor Profile Method," Proceedings of the AWWA Water Quality Technology Conference, Denver, Colorado, 12 pages, November 9-12, 1997.

[49] AWWA 1993

[50] *Standard Methods for the Examination of Water and Wastewater*, 21st edition, AWWA, APHA WEF, 2005.

[51] Krasner, S.W., McGuire, M.J., and Ferguson, V.B., "Tastes and Odors: The Flavor Profile Method," *Jour. AWWA*, Vol. 77, No. 3, pp. 34-39, March 1985.

[52] Doty, R.L., (ed.), *Handbook of Olfaction and Gustation*, second edition, Marcel Dekker, Inc., New York, 2003.

[53] Suffet, Mallevialle and Kawczynski 1995

[54] Mackey, Suffet and Booth 2009

[55] Krasner, McGuire and Ferguson 1985

[56] Shen et al. (1997a and 1997b)

57 Krasner and Barrett, 1984

58 Cohen, J.M., Kamphake, L.J., Harris, E.K., and Woodward, R.L., "Taste Threshold Concentrations of Metals in Drinking Water," *Jour. AWWA*, 52:5:660-670, 1960.

59 Lim, J., and Lawless, H.T., "Oral Sensations from Iron and Copper Sulfate," *Physiology & Behavior*, Vol. 85, pp. 308-313, 2005.

60 Glindemann, D., Dietrich, A., Staerk, H.-J., and Kuschk, P., "The Two Odors of Iron when Touched or Pickled: (Skin) Carbonyl Compounds and Organophosphines," *Angew. Chem. Int. Ed.*, Vol. 45, pp. 7006-7009, 2006.

61 Lawless, H.T., Schlake, S., Smythe, J., Lim, J., Yang, H., Chapman, K., and Bolton, B., "Metallic Taste and Retronasal Smell," *Chem. Senses*, 29:25-33, 2004.

62 Maine Bureau of Health Department of Human Services, "The presence of MTBE and other gasoline compounds in Maine's drinking water," Preliminary Report, October 13, 1998. (http://www.maine.gov/dhhs/eohp/wells/MTBESUM.PDF)

63 McGarry, F., "RE: thought re MTBE," Email to Ken Coburn, December 22, 2000.

64 McGuire, M.J., "Expert Report of Michael J. McGuire, PhD, PE, BCEE–Expert Opinions on Specific Wells," Prepared for United Water New York, Inc. v. Amerada Hess Corp. et al., 04 Civ. 2389, and County of Suffolk and Suffolk County Water Authority v. Amerada Hess Corp. et al., 04 Civ. 5424, United States District Court, Southern District of New York, August 22, 2007b.

65 NYCDEP website, http://www.nyc.gov/html/dep/html/drinking_water/groundwater.shtml , downloaded March 2, 2009.

66 NYCDEP website, http://www.nyc.gov/html/dep/html/drinking_water/groundwater04.shtml , downloaded March 2, 2009.

67 File Name: 356 Complaint spreadsheet referenced in November 13 2008 letter - (# Legal 2133112) V 2003.xls

68 McGuire 2007b

69 Health Canada, "Guidelines for Canadian Drinking Water Quality: Guideline Technical Document — Methyl *Tertiary*-Butyl Ether (MTBE)," Water Quality and Health Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario, 2006.